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TECHNO – ECONOMIC EVALUATION OF TRACTOR OPERATED RAISED BED PLANTERS AND SEED DRILLS FOR CULTIVATION OF WHEAT CROP

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ABSTRACT

A field experiment was conducted to evaluate performance of raised bed planters and seed cum-ferti-drill for cultivation of wheat crop in vertisol at research farm of J.N.K.V.V. Jabalpur (M.P.) during 2013-14. The field was arranged in two tillage levels as main treatment i.e. T_1- 1×cultivator + 1×disc harrow and T_2- 1×cultivator + 2×disc harrow and four sub-main treatment of sowing practices i.e. S_1–raised bed planter with 120 cm wide bed and 5 rows per bed, S_2–raised bed planter with 70 cm wide bed and 3 rows per bed, S_3–raised bed planter with 125 cm wide and 5 rows per bed and S_4–conventional seed-cum-fertilizer-drill and to validate it statistically split plot design was used. The field efficiency was found to be maximum in treatment S_4-T_2 (63.56%) and minimum in treatment S_3-T_1 (58.39%). The plant population, number of plants/meter length and plant height was found to be maximum in treatment S_2-T_2 (159 plants/m^2, 33 plants/m length and 957.3 mm). The maximum grain yield was found in S_2-T_2 (49.5 q/ha) and minimum in S_3-T_1 (40.2 q/ha) treatment. The source wise energy consumption found to be minimum in treatment S_1-T_1 (12658.5MJ/ha) and maximum in treatment S_1-T_2 (14007.1MJ/ha). While operation wise energy consumption was observed minimum in treatment S_4-T_1 (5488.9MJ/ha) and maximum in treatment S_1-T_2 (5873.0MJ/ha). The sowing machine S_2 gave the highest net return (66252.5Rs/ha). Therefore it can be concluded that sowing machine S_2 performed better in view of field efficiency, crop attributes and crop yield when field was prepared by 1 x cultivator followed by 2 x disc harrows (T_2).

***KEYWORDS:** Raised Bed Planting/Sowing, Field Efficiency, Grain Yield and Energy Consumption*

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Original Article

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the premier cereal crop of the world. In India, it is the second major food crop after rice. India is occupying about 30 million ha cultivated area and annual production is about 93.50 million tonnes with an average productivity of 3,177 kg/ha (DES, Ministry of Agriculture).India is the largest wheat producing country and contributing about 13.10% global wheat production (Food and Agriculture Organization figures from FAOSTAT database 2012). Madhya Pradesh is the third largest wheat producing state in the country after Uttar Pradesh and Punjab, with the average area, production and productivity are 5.97 million hectare, 14.47 million tones and 2925 kg/ha, respectively (Agriculture Statistics, MP Govt 2013).

Traditionally wheat had been sown by various methods like hand broadcasting or in furrows behind the animal drawn plough. With the increase of mechanization some tractor and bullock drawn implements are used to

enhance the production like seed cum fertilizer drill, zero till drill, roto till drilletc. In order to satisfy the tremendous food requirement of rapidly expanding human population, new production technologies are needed that increase yield with minimal input.

In the mid-1990s raised bed planting were introduced to Rice-Wheat (RW) cropping systems in the Indo-Genetic Plains (IGP), initially for wheat, inspired by the success of irrigated maize–wheat on permanent raised beds in Mexico (Sayre and Hobbs, 2004). Raised beds have proven to be an excellent option for wheat and are widely used in agriculture in developed countries (Singh et al., 2009). In raised bed planting system, fields are prepared conventionally and beds are formed manually or by tractor drawn raised bed formers or raised bed planter/seeder. Raised bed planters/seeder are used for preparing beds and sowing simultaneously, in this crops are planted in multiple rows on top of the bed and irrigation is applied in furrows made in between the bed, and by lateral movement through the soil water is reaches to the plants (Kumar et al., 2002). Bed planting has also been found to show improved water distribution and efficiency, fertilizer use efficiency and reduced weed infestation (Hobbs and Gupta, 2004). This technique also requires reduced seed rate as compared to flat sowing without sacrificing crop yield. Bed planting also ensures better crop stand and yield by improvement of root proliferation (Peries et al., 2001). It has also been reported that this system is more resistant to lodging than the crop sown on flat fields for wheat crop (Shukla et al., 1999). In adverse climate condition, excess rainwater drained out from the field through furrows to minimize its harmful effect on the crop (Kumar et al., 2002). Raised bed planting also provides a natural opportunity in conservation agriculture (CA) to reduce compaction by confining traffic to the furrow bottoms (Govaerts et. al., 2006).

In the last decade, yield of wheat has increased manifold, which leads to high energy inputs use. (Singh et. al., 2004). In field farmers used the various inputs i.e. tractor, agricultural machinery, diesel, electricity, seed, fertilizer, plant protection chemicals, farm yard manure, irrigation water etc in improper or excessive manner to get the high crop production. Efficient use of these inputs helps to earn higher production and productivity which contributes to economy, and competitiveness of agriculture sustainability to rural living (Singh H. et al 2002). Raised bed planting shows the better option for efficient use and minimal wastage of agricultural inputs and to get higher production with the given energy.

In Madhya Pradesh multiple cropping schemes are possible through the extension facility and mechanization. At present, various sowing methods are in use but raised bed planting for wheat crop is not vary popular as far as northern plain of India, because in this plain soil conditions are not quite favorable for bed formation and farmers also do not have a prior information about the bed planting system. In vertisol, adverse climate condition effect the wheat production. Therefore, the study was undertaken in vertisol to determine the effects of raised bed sowing over conventional flatbed sowing for productivity of wheat crop

Objectives of Investigation

The present study is based on the following objectives

- To study the performance evaluation of different types of raised bed planters and seed drills for the cultivation of wheat crop in vertisol.
- To study economics and energy requirement for different raised bed techniques for cultivation of wheat crop.

MATERIALS AND METHODS

Study Site Description

This study was established at experimental station of Jawaharlal Nehru KrishiVishwa Vidyalaya Jabalpur (M.P.) during 2012-13. The university is located at 23°13’15.32” N longitude and 79°57’ 50.82” E latitude and 390 m above MSL. The region has a humid-subtropical climate, with hot humid summer and cool winter. The soil of the experimental field was classified as vertisol which contains sand-29.10%, silt-20.15%and clay-50.75% with pH 7.5- 8.0 and bulk density 1.1.-1.25 kg/m^3. The mean annual precipitation is 1353.8 mm which occurs 80% during man soon period.

Experiment Layout and Treatments

This experiment compared three different raised bed planters /seed-drill with conventional seed cum fertilizer drill for wheat in a split plot design with three replications. The field was arranged in two tillage levels for seed bed preparation as main treatment i.e. T_1 - 1 × Cultivator + 1 × Disc Harrow and T_2 - 1 × Cultivator + 2 × Disc Harrow and four sub-main treatment of sowing practices are S_1 – Jawahar raised bed seed drill (120 cm wide, 5 rows per raised bed), S_2 – National raised bed planter (70 cm wide, 3 rows per bed), S_3 – Pant nagar raised bed planter (125 cm wide, 5 rows per bed) and S_4 – Conventional seed-cum-fertilizer-drill. The technical specification of various sowing machine are presented in table 1. The field experiment was conducted in a field of 35m X 35m size. The field was divided in 24 sub plots and unit plot size was 24 m^2.Wheat (GW-273) was sown at the rate of 100 kg/ha on 20 October2012 and harvested on 30 April 2013. The recommended dose of fertilizer in the ratio of 120:60:40 of Nitrogen: Phosphorous: Potassium per hectare was applied in the field. The phosphorous, potassium is wholly applied during sowing and nitrogen is applied in dozes 30% during sowing as basal doze and 30% after three weeks and rest of 40% after five weeks as top dressing.

Data Collection and Sampling

Machine parameters like fuel consumption, actual field capacity and field efficiency were recorded at the time of operation. Crop parameters i.e. plant height, plant population, plants per meter length and number of tillers per ear head were measured at regular interval after sowing. Yield and yield attributes from all the treatments were collected at the harvesting stage with the help of “Crop Cutting Yield” method. In this method the crop samples were harvested from the random locations of all the treatments with the help of 1 × 1 m^2 size square frame. The grain was separated and weight was determined using an electronic balance. The cost of cultivation, net returns and benefit: cost ratio (B: C ratio) were calculated by using prevailing prices of inputs and outputs. All the data were subjected to analysis of variance (ANOVA) as per the standard procedure as describe by Panse and Sukhamte (1985).

Table 1: Technical Specification of Various Sowing Machine Used in Experiment

Parameter	J.R.B.S.D (S_1)	N.R.B.P. (S_2)	P.R.B.P. (S_3)	C.S.C.F.D(S_4)
Overall Dimensions:				
Length, mm	1610	1600	1650	1100
Width, mm	1900	2110	2150	2180
Height, mm	1350	1300	1500	1250
Depth of Sowing, mm	50-55	50-55	50-55	50
Row to row spacing, mm	225	200	225	225
Type of tines	Reversible shovel	Inverted T-type	Shoe type	Shoe type
No. of tines	5	6	5	6
Working width, mm	1125	2220	1120	2100

Table 1: Contd.,				
Ground wheel dia., mm	380	380	370	360
No. of bed	1	2	1	-
Dimensions of bed, mm	1200 X 1700	700 X 1700	1250 X 180	-
Dimensions of ridge, mm	270 X 170	220 X 170	300 X 80	-

J.R.B.S.D: Jawahar Raised Bed Seed Drill, N.R.B.P.: National Raised Bed Planter, P.R.B.P.: Pantnagar Raised Bed Planter, C.S.C.F.D.: Commercial Seed-Cum-Ferti-Drill

Energy Requirement

The energy use pattern for production of wheat crop were determine according to sources and operation to be use dat various treatments. The source wise energy includes human, diesel fuel, tractor, electricity, seed, farm yard manure, fertilizer, chemical and machinery as a input whereas operation wise energy shows energy consumed at various operation i.e. tillage, sowing, inter-culture, irrigation, top dressing, harvesting and threshing. To estimate the output and input energy, physical quantities of each ingredient used as input and output were converted into energy equivalents (MJ/ha) by multiplied them with their energy conversion factor. The energy equivalents of various inputs used in cultivation of wheat crop are present in table 2

Table 2: The Energy Equivalents of Various Agriculture Inputs

Energy Sources	Units	Equivalent Energy (Mj/Unit)	Reference
Human			
• Man	h	1.96	Mandal et. al., 2002, Singh et. al., 2002 and Yilmaz et. al. 2005.
• Woman	h	1.57	Mandal et. al., 2002 and Singh et. al., 2002.
Agricultural Machinery	h	62.7	Singh 2002 and De et. al., 2001
Diesel	l	56.31	Singh 2002 and De et. al., 2001
Fertilizer			
• Nitrogen (N)	kg	60.60	Singh 2002
• Phosphorus (P_20_5)	kg	11.10	Singh 2002
• Potassium (k_20)	kg	6.70	Singh 2002
Farm Yard Manure	kg	0.3	Singh 2002
Electricity	kWh	11.93	De et. al., 2001
Chemical			
• Superior (need dilution)	l	120	Mandal et. al., 2002 and Singh et. al., 2002.
• Inferior(not need dilution)	kg	10	Mandal et. al., 2002 and Singh et. al., 2002.
Seed (Wheat)	kg	14.7	Mandal et. al., 2002, Singh 2002 and De et. al., 2001
Straw	kg	12.5	Singh 2002 and De et. al., 2001

a) Jawahar Raised Bed Seed Drill **b)National Raised Bed Planter**

c) Pantnagar Raised Bed Planter **(d)Conventional Seed Cum Fertilizer**

Figure 1: View of Different Sowing Equipment Operated in the Field

Figure 2: View of Experimental Field After 90 Days of Sowing

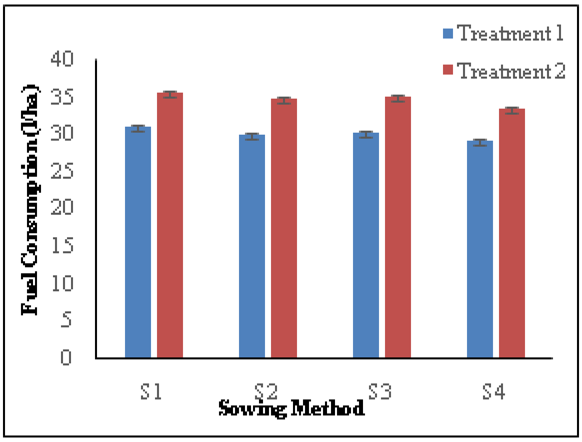
RESULTS AND DISCUSSIONS

Field Efficiency and Fuel Consumption

The field efficiency and fuel consumption of various treatments were measured and shown in figure 3.The field efficiency and fuel consumption of various sowing machines were significantly ($P \geq 0.05$) affected by tillage methods. The field efficiency of J.R.B.S.D. (S_1), N.R.B.P. (S_2), P.R.B.P. (S_3) and C.S.C.F.D. (S_4) were found to be 60.09%, 60.5%, 58.39% and 62.85% in treatment T_1 and 61.2%, 61.7%, 60.34% and 63.56% in treatment T_2 respectively. The average field efficiency of both the tillage level was minimum in S_3 (59.37%) and maximum in S_4 (63.20%). Higher field efficiency was observed in case of S_4treatment in both the tillage level due to lesser wheel slippage as the machine operated at shallow

depth and better maneuverability with tractor causing less time in turning. The lowest field efficiency was achieved in case of S_1 in tillage level T_1. Field efficiency of all raised bed planters was less than the conventional seed cum fertilizer drill because of higher rolling resistance to overcome the soil forces and more draft required for preparing beds and sowing simultaneously.

Fuel consumption for S_1, S_2, S_3, and S_4 were found to be 30.86, 29.72, 30.06 and 28.86 l/ha in treatments T_1 and 35.37, 34.68, 34.95 and 33.31l/ha in treatment T_2 respectively. The above mentioned fuel consumption indicates cumulative values which includes fuel consumed during seed bed preparation and sowing operation .In treatment T_2, fuel consumption was higher as compare to T_1 because of one extra pass of disc harrow for seed bed preparation. The average fuel consumption was observed maximum in S_1 (33.11l/ha) and minimum in S_4 (31.08l/ha)whereas in other two practices S_2 and S_3 fuel consumption was higher as compare to S_4 but lower than S_1.



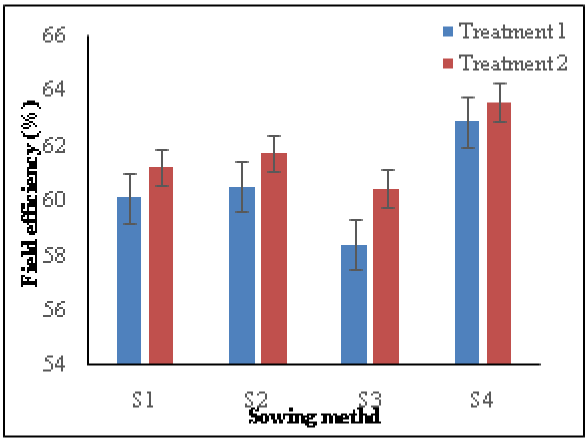


Figure 3: Fuel Consumption and Field Efficiency of Various Ng Implement in Both the Treatments

Crop Growth Parameters

- **Plants Population**

The plant population in various treatments were analyzed statistically at 45, 60, 75 and 90 DAS and presented in table 3. The analysis of data revealed that significant variation was established due to main treatment and sub treatment in plant population and plants per meter length after 45, 60, 75 and 90 days of sowing at 0.05 significant level.

The highest plant population was observed in N.R.B.P. (S_2) 158, 157, 157 and 156 plants/m² in treatment T_1 and 162, 161, 160 and 159 plants/m² in treatment T_2 whereas lowest plant population was found in P.R.B.P. (S_3) 151, 151, 149 and 148 plants/m² in treatment T_1 and 155, 154, 153 and 152 in treatment T_2 after 45, 60, 75 and 90 Days of sowing, while other two methods J.R.B.S.D (S_1) and C.S.C.F.D. (S_4) shows the almost similar numbers of plant population in their individual treatments. Lowest plant population for S_3 in treatment $T_1$was observed due to low percentage of seed emergence (92.8%).In treatment T_2 though the seed emergence was almost similar but higher plant population was observed under S_2. This may be attributed to the fact that probably better crop establishment occurred when seed bed was prepared using 1 x cultivator followed by 2 x disc harrow.

Table 3: Plant Population after 45, 60, 75 and 90 Days of Sowing in Various Treatments

Sub Treatment	Plant Population (No. of Plant/m2)							
	Main Treatment							
	T_1				T_2			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
S_1	154	153	153	152	156	156	155	154
S_2	158	157	157	156	162	161	160	159
S_3	151	151	149	148	155	154	153	152
S_4	155	154	154	152	159	157	157	156
	$(S \times T)_1$				$(S \times T)_2$			
S.Em±	1.7	1.58	1.22	1.67	0.87	0.87	0.94	1.29
C.D. (5%)	6.67	6.68	4.77	6.54	2.52	2.52	2.75	3.76

DAS: Days after sowing

- **Plants Per m Length**

Plants per meter length were analyzed statistically and a significant variation at 5 % level was established due to main treatment and sub treatment in plant per meter length at 0, 15, 30 and 45 days after sowing and the data were present in table 4. The maximum plants per meter length after 45 days of sowing were observed in S_2 in both the tillage levels T_1 and T_2, while minimum plants were observed in S_3because in this treatment seeds were covered by excessive soil during the operation which causes the problem of aeration and deficiency of fertilizer which was necessary to withstand the plants in various environment condition.

Table 4: Plants Per Meter Length in Various Treatments after 0, 15, 30 and 45 Days of Sowing

Sub Treatment	Plant per Meter Length							
	Main Treatment							
	T_1				T_2			
	0 DAS	15 DAS	30 DAS	45 DAS	0 DAS	15 DAS	30 DAS	45 DAS
S_1	31	30	29	29	33	32	31	31
S_2	33	31	32	32	34	34	34	33
S_3	31	29	29	28	33	31	31	29
S_4	31	31	30	30	33	32	31	31
	$(S \times T)_1$				$(S \times T)_2$			
S.Em±	0.71	0.71	0.75	1.08	0.82	1.15	0.91	0.85
C.D. (5%)	2.77	2.77	2.96	4.23	2.38	3.36	2.66	2.48

- **Height of Plant**

The plant height in various treatments were varies significantly up to 60 days of sowing but latter on no significant variation was observed in plant height. The table 5 shows the plants height after 15, 30, 45, 60, 75 and 90 DAS in different treatments. It is evident from the results that plants height of various sowing methods in treatment T_2 were significantly higher than treatment T_1 because of greater soil pulverization which enhances the initial growth rate. The overall plant height after 90 Days of sowing was almost same in all treatments. The lowest height of plants was found in case of S_1 in treatment T_1 because of higher soil strength and greater soil aggregate size.

Table 5: Height of Plant of Wheat Crop in Various Treatments

Sub Treatment	Plant Height (Mm)											
	Main Treatment											
	T_1						T_2					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
S_1	115.6	239.6	445	678.6	926	940.3	118.3	225.7	487.3	730.6	936.7	941.3
S_2	120.7	243.7	456	695	950.3	953	125	262	487.3	752	952	957.3
S_3	114	234	443.4	691	931.6	947.6	117.3	246	452.3	745	946.3	950.3
S_4	116.7	239.3	458.6	704	938	951.6	123	252.6	469	743.3	943.6	951.3
	$(S X T)_1$						$(S X T)_2$					
S.Em±	3.34	3.58	7.43	9.37	7.97	10.91	1.79	4.24	10.77	13.83	8	6.36
C.D. (5%)	13	14	29.1	36.6	31.2	42.75	5.21	12.35	31.36	40.28	23.31	18.52

- **Weed Count**

Number of the weed before and after field preparation/sowing was measured and shown in Figure 4. Initially the experimental field had 12 number of weeds count/m² area. The maximum weeds were observed in S_4 in tillage treatment T_1, because of less soil manipulation and minimum weeds were found in S_2 in tillage treatment T_2.

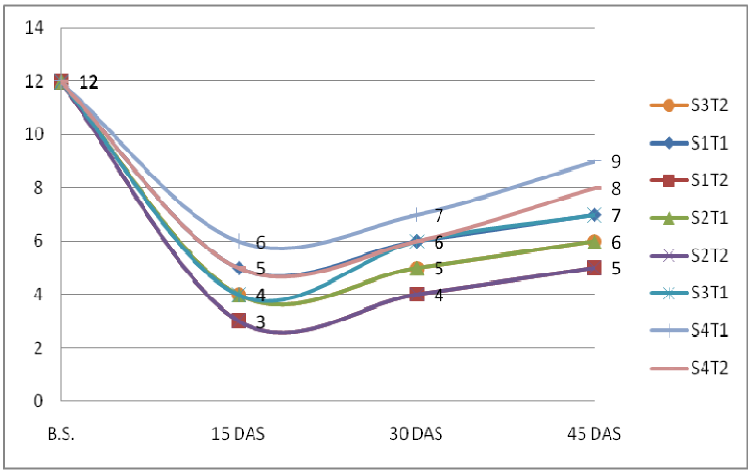


Figure 4: Number of Weeds in Various Treatments at 15 Days Interval

Grain Yield Attributes

The data for grain yield, straw-grain ratio and weight of 1000 grains from various treatments were analyzed statistically. The grain yield per hectare of four different sowing machines was significantly ($P \geq 0.05$) influenced by tillage levels. The data presented in table 6 shows that grain yield in tillage level T_2 of all four machines significantly higher than the grain yield in tillage level T_1.On the basis of various sowing practices average grain yield were found to be 43.2, 47.3, 40.5 and 42.2q/ha in S_1, S_2, S_3 and S_4 respectively. While comparing tillage levels the average yield 42.2q/ha was found in T_1 and 44.4q/ha in T_2. The straw grain ratio in different treatments were measured and among all the treatments highest straw-grain ratio was observed in treatment S_2-T_2 (1.31:1). The weight of 1000 grain was also measured under all the treatments, and the highest weight was found in treatment S_2-T_2 (43.4g) which shows the health of germinated seeds and lowest in S_3-T_1 and S_4-T_1 (38.7g).

Table 6: Crop Yield Parameter under different Treatments

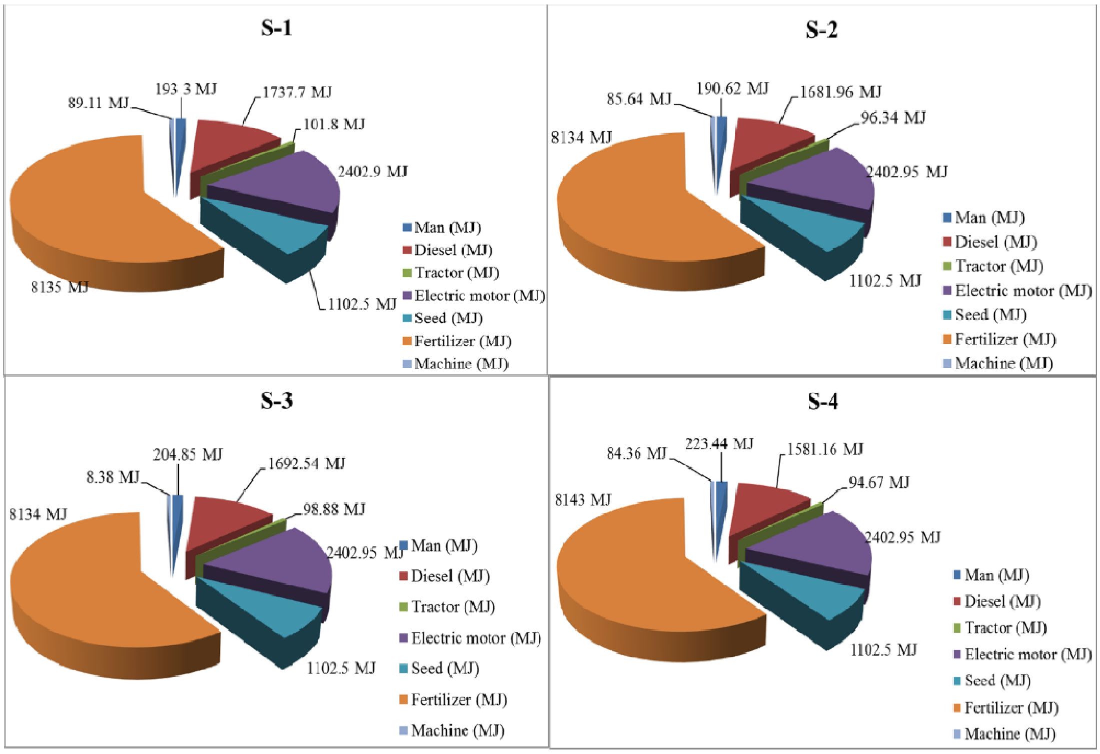
Sub Treatment	Crop Yield Parameter					
	Main Treatment					
	T1			T2		
	Grain Yield (kg/ha)	Straw Grain Ratio(%)	1000 Grain weight (g)	Grain Yield (kg/ha)	Straw Grain Ratio (%)	1000 Grain Weight (g)
S1	42.6	1.21	38.9	43.8	1.23	40.3
S2	45.1	1.23	41.8	49.5	1.31	43.4
S3	40.2	1.24	38.7	40.8	1.27	40.3
S4	40.9	1.22	38.7	43.5	1.23	40.1
	$(S \times T)_1$			$(S \times T)_2$		
S.Em	1.36	0.03	0.78	1.66	0.02	0.67
C.D. (5%)	5.32	0.12	3.07	4.8	0.07	1.95

Energy Requirement

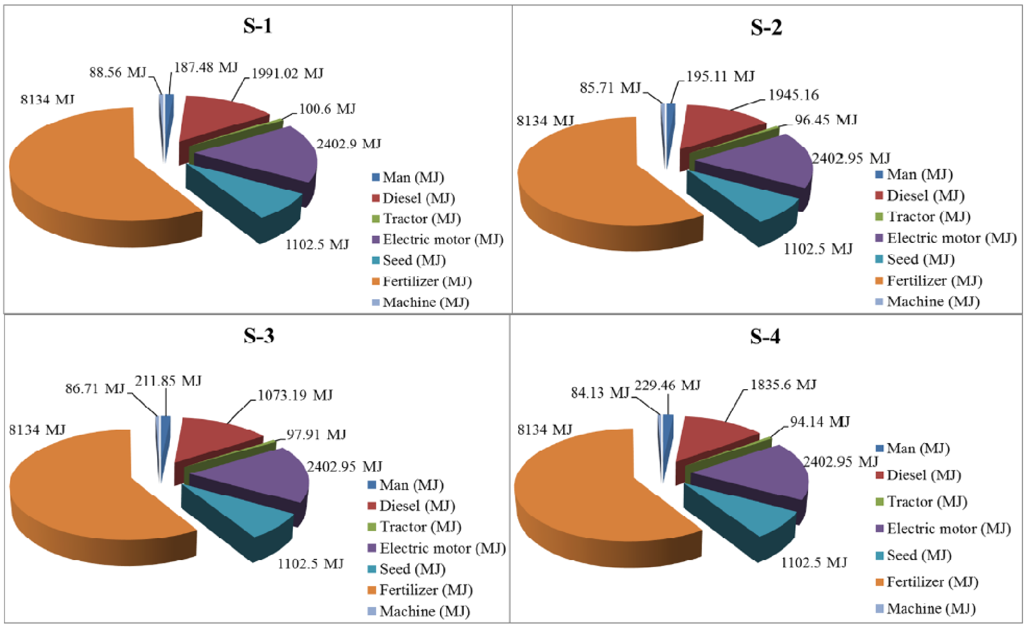
Source Wise Energy (MJ/Ha) Consumption under Different Treatments

Source wise energy consumption i.e. man, diesel, tractor, machine, electric motor, seed and fertilizer under different treatments were measured and the energy consumed by each source were presented in figure 5. The energy consumed by electric motor, seed and fertilizer was same in all treatments because of same irrigation schedule, seed and fertilizer rate in all the treatments.

The source wise energy consumption for S_3 (12658.5MJ/ha) in treatment T_1 was found to be minimum whereas maximum energy were consumed in S_1 (14007.1MJ/ha) and S_3 (14009.1 MJ/ha) in tillage level T_2. The individual energy source like man energy was lowest in S_1-T_2 (187.48 MJ/ha) and highest in S_4-T_2 treatment (229.46 MJ/ha), Diesel energy was lowest in S_4-T_1 (1581.16 MJ/ha) and highest in S_1-T_2 (1991.02), tractor energy was lowest in S_4-T_2 (94.14/ha) and highest in S_1-T_1 (101.8) similarly machine energy was lowest in S_2-T_1 (85.64 MJ/ha) and highest in S_1-T_1 (89.11MJ/ha)



(a)Treatment -1

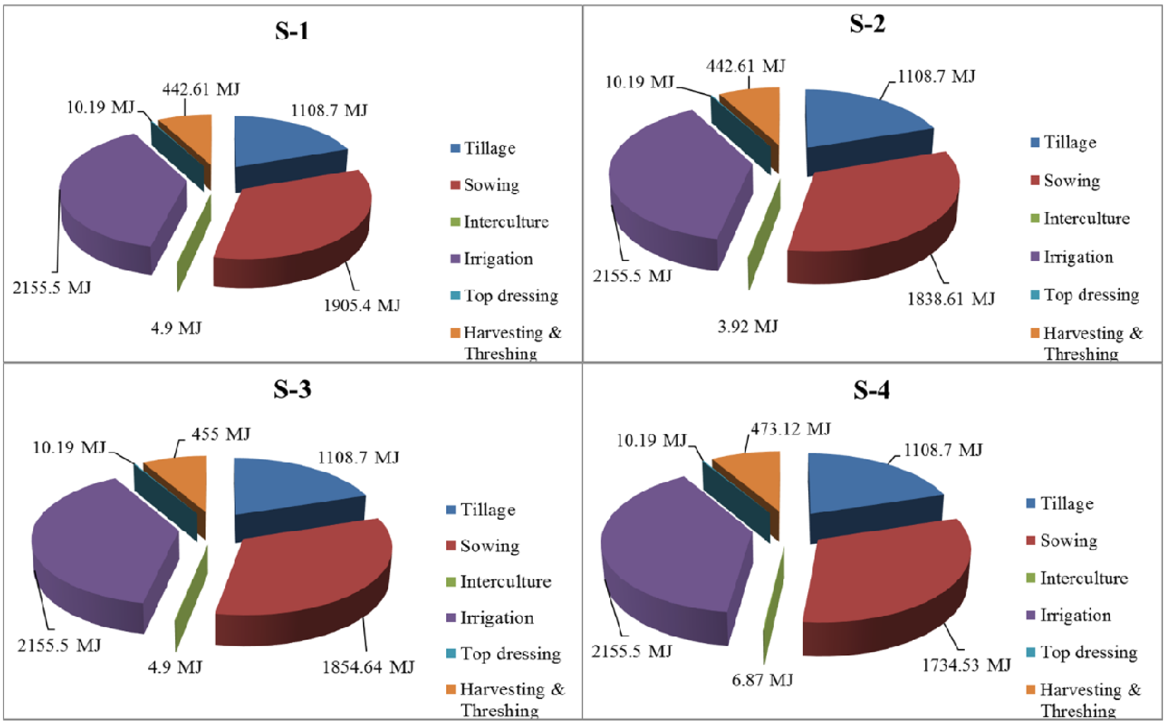


(b)Treatment - 2

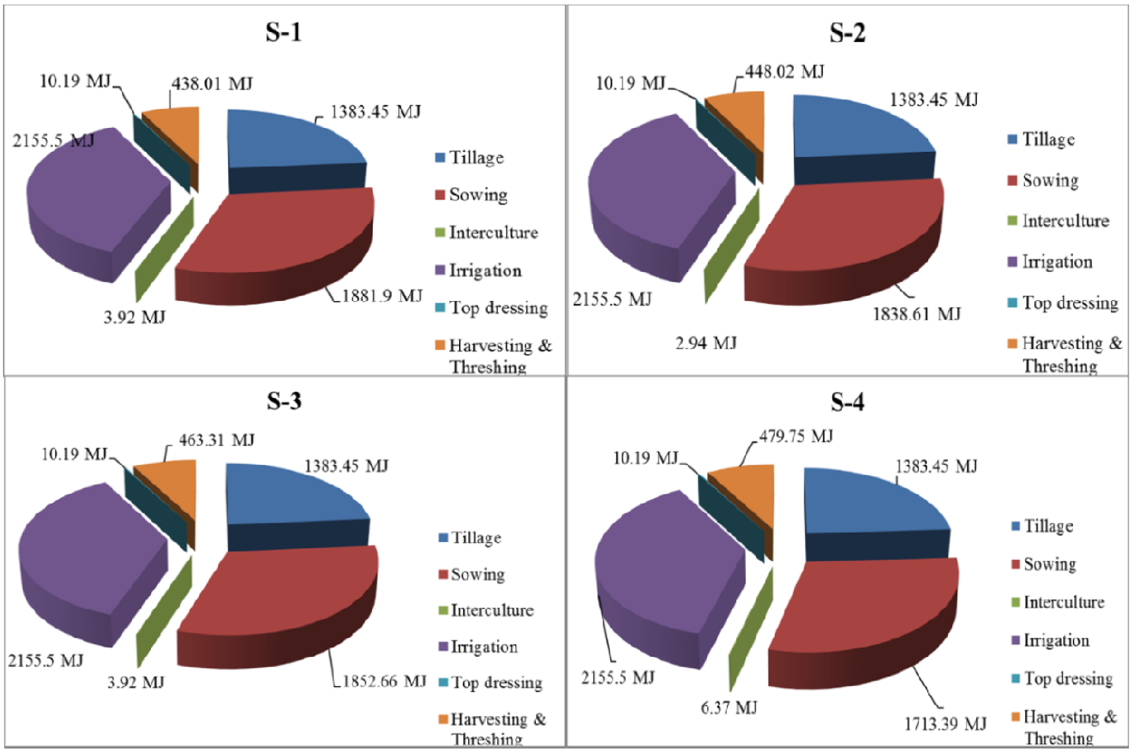
Figure 5: Source Wise Energy (MJ/Ha) Consumption for Different Sowing Machinery under Two Tillage Level

Operation Wise Energy (MJ/ha) Consumption under Different Treatments

The operation wise energy consumption (figure 6) for sowing machine S_1, S_2, S_3 and S_4 in tillage level T_1 were 5627.4, 5559.6, 5588.9 and 5488.9MJ/ha whereas in tillage level T_2 it were 5873.0, 5838.7, 5859.0 and 5748.6MJ/ha respectively. The energy consumption in irrigation and top dressing operation were same in all treatments which are 2155.6 and 10.19MJ/ha respectively because of same quantity and schedule. The energy consumed in sowing operation was highest in case of S_1 1905.4MJ/ha in tillage level T_1, while lowest energy consumed by S_4 in both the tillage level, i.e. 1734.5MJ/ha in T_1 and 1713.3MJ/ha in T_2. The maximum energy in interculture operation was observed in S_4 (6.87MJ/ha) treatment in tillage level T_1 whereas minimum energy was observed in S_2 (2.94MJ/ha) treatment in tillage level T_2. Similarly energy consumed in harvesting and threshing operation was highest in S_4 in both tillage level and lowest in S_1 in tillage level T_2.



(a)Treatment – 1



(b)Treatment – 2

Figure 6: Operation Wise Energy (MJ/Ha) Consumption for Different Sowing Machinery under Two Tillage Level

Cost of Operation

The cost of operation (seed bed preparation + sowing) was found to be highest in S_1-T_2 (3572.7 Rs/ha) treatment and lowest in S_4-T_1 (2713.9Rs./ha) treatment whereas total cost of production was found to be highest in case of S_3

(8264.7Rs/ha) and S_4 (8331.8 Rs/ha) in tillage level $T_2$and lowest in S_2(7427Rs/ha) in tillage level T_1.The benefit cost ratio of S_2 (8.28:1) in tillage treatment T_2observed highest while in S_3 (6.40:1) treatment with tillage level T_2 it observed lowest. The highest net return (income) was achieved in S_2 (66252.5 Rs/ha) with tillage level T_2 and lowest in S_3 (52472.6 Rs/ha) with tillage level T_1.

CONCLUSIONS

This research was carried out to evaluate the performance of different raised bed planter/seed drill for cultivation of wheat crop in vertisol. The following conclusions have been drawn from the study undertaken:

- The field efficiency was found to be maximum (63.56%) in treatment S_4-T_2 and minimum (58.39%) in treatment S_3-T_1. It may be due to less overlapping and better steering with conventional seed cum fertilizer drill.
- The highest fuel consumption was found to be in treatment S_1-T_2 (35.37 l/ha) and lowest in S_4-T_1 (28.86 l/ha).
- The plant height was almost equal till 15 DAS, however significant difference was observed later on. The plant height was comparatively more in S_2, this may be because of better manipulation of soil which probably helped in more root growth.
- On an average the grain yield was 43.2, 47.3, 40.5 and 42.2 q/ha in S_1, S_2, S_3 and S_4 respectively. While comparing tillage methods the average yield 42.2 q/ha was found in T_1 and 44.4q/ha was found in T_2. Therefore, it can be said that there was significant effect of sowing method on yield and strong correlation was observed between yield and tillage level.
- The source wise energy was minimum (12658.5 MJ/ha) in treatment S1-T1 and maximum (14007.1 MJ/ha) in treatment S1-T2 whereas operation wise energy was minimum (5488.9 MJ/ha) in treatment S4-T1 and maximum (5873.0 MJ/ha) in treatment S1-T2.

On the basis of study it can be concluded that National Raised Bed Planter (S_2) requires less cost of operation than other raised bed planters for wheat cultivation and gave the higher grain yield when operated in tillage level T_2 and gave the highest net return (66252.5 Rs/ha).

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